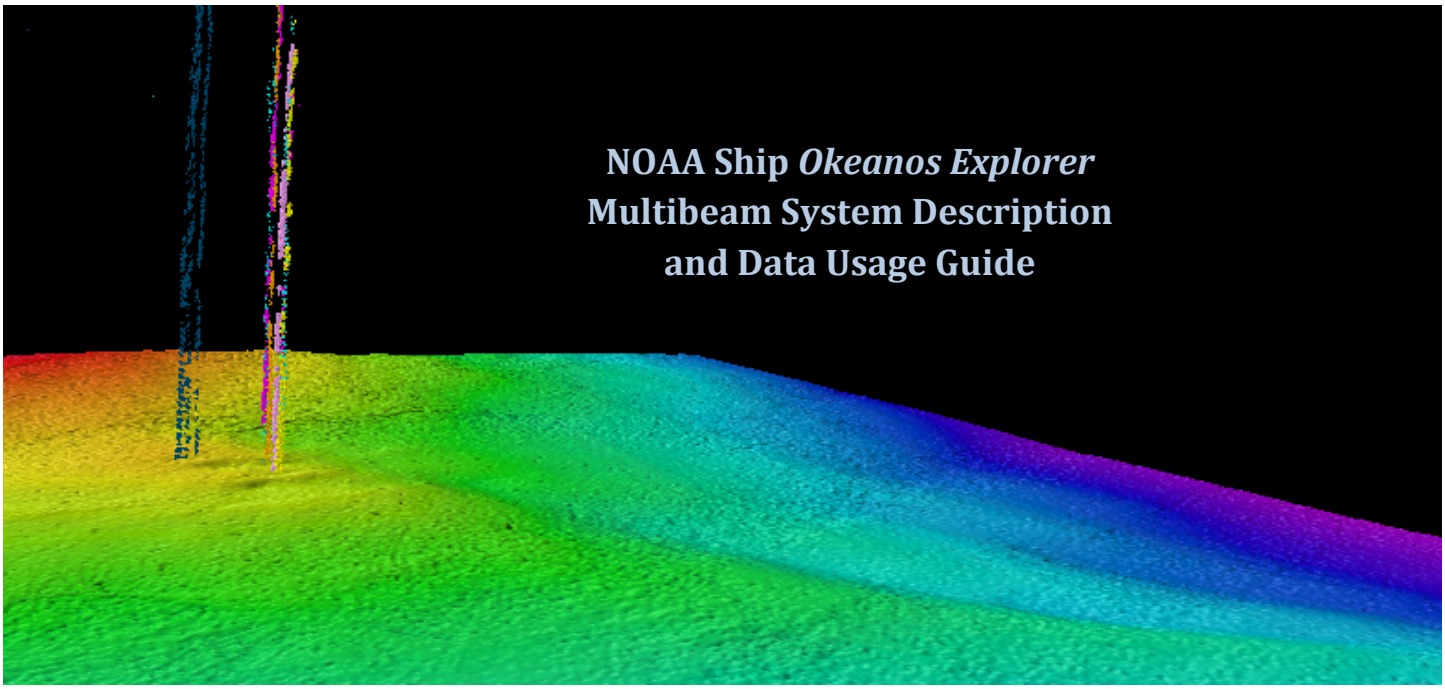

Purpose

This document briefly describes NOAA Ship *Okeanos Explorer's* multibeam mapping system, multibeam data acquisition and processing methods, and methods to access public data holdings. In pursuit of the NOAA Office of Ocean Exploration and Research's mission to *Always Explore*, the ship's multibeam system is operated by trained watchstanders during all cruises, including during transit.

Questions? Contact:
oar.oer.exmappingteam@noaa.gov
www.oceanexplorer.noaa.gov

Kongsberg Maritime EM 302 Multibeam System Description

The *Okeanos Explorer* is equipped with a Kongsberg Maritime EM 302 multibeam sonar system. The sonar system hull installation was completed by Todd Shipyard in Seattle in March 2008, and accepted after field tests in September 2008. The EM 302 receiver and transmit array are arranged in a Mills Cross formation on the transducer fairing. The nominal frequency of the EM 302 is 30 kHz. The system can be operated in two modes – CW (continuous waveform) or FM (frequency modulated) mode. The distinctive advantage of FM mode is that a larger swath can be achieved as compared to traditional deep water multibeam systems.

Depth Range

The EM 302 is designed to map the seafloor in water depths of 10 to 7000 meters, and in fact was able to detect the seafloor at 8000 meters over the Mariana Trench. This leaves only the deepest parts of the deeper ocean trenches out of the EM 302's reach. The maximum observed swath of the EM 302 is approximately 8 kilometers, and diminishes in depths greater than 6000 meters.

Multiple Data Types Collected

Bathymetry: FM chirp mode is utilized in water depths greater than 1000 meters, and allows for the detection of the bottom further out from nadir than with previous 30 kHz systems. This results in wider swath widths and more seafloor mapped, although sometimes results in artifacts in outer beams.

Seafloor Backscatter: The system collects seafloor backscatter data, which provides information about the character of the seafloor in terms of bottom type.

Water Column Backscatter: The system also collects water column backscatter data, which has the proven ability to detect gaseous plumes in the water column.

EM 302 Survey Planning Guidance

The following table provides a rough estimate for survey times. Actual survey times will vary depending on seabed type and environmental conditions.

Water Depth (m)	Speed (kts)	Time (approx) to Map 100 KM^2	Time (approx) to Map 1,000 KM^2	Time (approx) to Map 10,000 KM^2
500-1500	5	5.5 h	44 h	18 d
	7	4.3 h	32 h	13.4 d
	9	3.6 h	25 h	10.5 d
1500-3000	5	4.4 h	34 h	13 d
	7	3.2 h	24 h	9.7 d
	9	2.7 h	19 h	7.6 d
3000-6000	5	3.4 h	23 h	8.1 d
	7	2.1 h	16 h	6 d
	9	1.8 h	13 h	4.7 d
6000-8000?	5	4.4 h	34 h	11.3 d
	7	3.2 h	24 h	8.3 d
	9	2.7 h	10 h	6.6 d

Table 1. EM 302 approximate survey time estimates.

Data Acquisition and Quality Control

Okeanos Explorer conducts an annual multibeam patch test during the annual shakedown cruise prior to field season mapping operations or when required after any major changes in the system setup (hardware or software). The patch test ensures all horizontal and vertical offsets are understood and accounted for in the data. The full results of the patch test can be found in the ship's annual readiness report. Additionally, EM 302 built in system tests (BIST) are conducted prior to and throughout every cruise to closely monitor system integrity.

Multibeam data are acquired using Kongsberg's Seafloor Information System (SIS). During data acquisition multibeam data quality is continuously monitored in realtime by acquisition watchstanders. Expendable bathythermographs (XBTs) are used to estimate sound speed profile of the water column every two to four hours as necessary to maintain data quality. Ship speed is adjusted to maintain data quality as necessary. Typical ship speed during data collection is 8-9 knots. Line spacing is typically planned to ensure ¼ to ½ swath overlap between lines at all times. Cutoff angles in SIS are typically set to 70° on both the port and starboard sides.

During data acquisition, sensor vertical and horizontal offsets, real-time vessel motion corrections, and sound velocity profiles are applied in real time, and therefore application during post processing is not necessary. Specifically these include ship attitude, sound speed at sonar head, sound speed profile, sonar offsets from the reference point, and sonar draft. Tidal corrections are not applied, and if desired by the end user should be post-applied.

Data Processing Pipeline

Raw multibeam bathymetry data files acquired by SIS are imported into CARIS. In CARIS, attitude and navigation data stored in each file are checked, and erroneous soundings are flagged using CARIS Swath Editor and Subset Editor. Cleaned, gridded bathymetric data are exported to ASCII text files (x,y,z) in WGS datum at resolution commensurate with the survey depths. The ASCII files are then used to create Fledermaus SD objects. These SD objects are then exported to geotiff and Google Earth KMZ. During all cruises, updated cumulative processed files are available on a daily basis on the ship and onshore via automated transfer to the Okeanos Explorer FTP.

Additionally, each cleaned multibeam line is exported in full resolution to ASCII text file (x,y,z) and is available at the National Geophysical Data Center's multibeam archival center for download within 60-90 days of the end of a cruise.

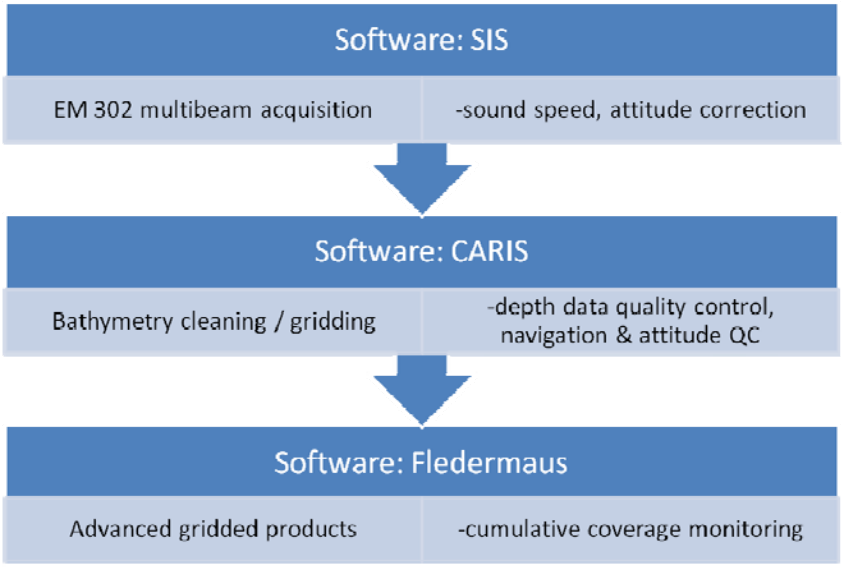

Figure 1. Shipboard multibeam bathymetry data flow.

Bottom backscatter and water column backscatter data are processed at sea using Fledermaus Geocoder Tools and MidWater on an as-needed basis for exploration decision making purposes. Typical bottom backscatter products include flat geotiffs and draped backscatter SD objects. Typical water column backscatter products include SD point objects. All data products produced offshore are sent to the public archives.

Public Data Archives

All NOAA Ship *Okeanos Explorer* data are archived in the National Geophysical Data Center's multibeam archives accessible with metadata through the following websites within 60-90 days of the end of every cruise:

Map Interface:

http://maps.ngdc.noaa.gov/viewers/bathymetry/

Text Interface:
http://www.ngdc.noaa.gov/nndc/struts/results?op_0=l&v_0=&op_1=l&v_1=&t=101378&s=300&d=21&d=411&d=79

During cruises, daily multibeam updates are provided via the National Coastal Data Development Center's Okeanos Explorer Digital Atlas:

http://www.ncddc.noaa.gov/website/google_maps/OkeanosExplorer/mapsOkeanos.htm

Data Formats

All EM 302 data collected by SIS are stored in Kongsberg data format with file extensions as *.all or *.wcd. During post processing at NGDC, the bathymetry and bottom backscatter *.all files are run through MB System to create *.mb58 files which are made available for downloading to public. The

conversion to *.mb58 files does not result in information loss, and the EM 302 datagram format is publically available through Kongsberg Maritime. *.Wcd files can be obtained by contacting NGDC.

Reports

In order to facilitate ease of use of all mapping data by all future explorers and researchers, a Mapping Data Report is generated for each cruise. The constantly evolving report describes data collection and processing methods, and details of exploration focus areas. The reports reside in the NOAA Central Library and are also available through the mapping team upon request.

Data Density and Resolution

In general, higher multibeam sounding density enables the production of finer resolution maps of the seafloor. It is therefore a goal of *Okeanos Explorer* to collect the highest density data possible, in balance with other cruise objectives. In water depths 3300 meters and shallower, the EM 302 is operated in dual swath, or multi-ping mode, which results in increased along track data density by detecting two swaths per ping cycle.

The *Okeanos Explorer* mapping team typically operates the multibeam in high density equidistant ping mode, which results in up to 864 evenly spaced soundings on the seafloor per ping.

Estimated across track EM 302 acoustic beam footprint in meters (high density ping mode, 432 soundings/profile)				
	Angular swath			
Water depth (m)	1 deg RX center	90° from nadir	120° from nadir	140° from nadir
100	1	0.5	1	1
200	2	1	2	3
400	4	2	3	5
1000	7	4	6	10
2000	18	9	16	25
4000	35	19	32	-
6000	70	37	-	-
7000	105	56	-	-

Table 2. Estimated across track EM 302 beam footprint. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 17.

Estimated along track EM 302 acoustic beam footprint in meters		
Water Depth (meters)	**Vertical**	**Near swath outer edge**
50	0.4	1.3
100	0.9	2.6
200	1.8	5.2
400	3.5	10.4
1000	8.8	26.1
2000	17.5	52.2
4000	35.1	104.4
6000	52.6	113.3

Table 3. Estimated along track EM 302 beam footprint. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 14.

Estimated across track EM 302 sounding density (distance in meters between soundings) (high density ping mode, 432 soundings/profile)			
Water depth (m)	**Swath Width**		
	90 deg	120 deg	140 deg
100	0.2	0.4	0.9
200	0.5	0.8	1.7
400	0.9	1.6	3.5
1000	1.9	3.2	6.9
2000	4.6	8.1	17.4
4000	9.3	16.2	-

Table 4. Estimated across track EM 302 sounding density. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 17.

Estimated ping rate and alongtrack resolution for EM 302					
140 deg swath, two profiles per ping (dual swath)					
Water depth (m)	Swath Width (m)	Ping Rate	Alongtrack distance between profiles (m)		
			@4 kts	@8 kts	@12 kts
50	275	3.2	0.3	0.6	0.9
100	550	1.8	0.6	1.1	1.7
200	1100	1	1.1	2.1	3.2
400	2200	0.5	2	4.1	6.1
1000	5500	0.2	5	10	15
2000	8000	0.1	7.6	15.2	22.8

Table 5. Estimated ping rate and along track EM 302 sounding density, two profiles per ping. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 15.

Estimated ping rate and alongtrack resolution for EM 302					
140 deg swath, one profile per ping					
			Alongtrack distance between profiles (m)		
Water depth (m)	Swath Width (m)	Ping Rate (pings/second)	@4 kts	@8 kts	@12 kts
50	275	3.2	0.7	1.2	1.9
100	550	1.8	1.1	2.2	3.3
200	1100	1	2.1	4.2	6.3
400	2200	0.5	4.1	8.2	12.2
1000	5500	0.2	10	20	30
2000	8000	0.1	15.2	30.5	45.7
4000	8000	0.06	19.2	38.5	57.7
6000	8000	0.04	24.5	49	73.4

Table 6. Estimated ping rate and along track EM 302 sounding density, one profile per ping. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 15.